

**METHOD AND APPARATUS FOR SWITCHING MOBILE STATION
BETWEEN AUTONOMOUS AND SCHEDULED TRANSMISSIONS**

TECHNICAL FIELD:

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This invention relates generally to mobile wireless communication systems and, more specifically, relates to methods and apparatus for operating a mobile station, such as a cellular telephone, with a base station when sending data on a reverse channel from the mobile station to the base station in a cdma2000-type system.

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BACKGROUND:

In a data communications system where a transmission resource is shared by multiple users, or where the transmission quality of a user can be affected by another user, there 15 are generally two modes of channel operation. These may be referred to generally as an autonomous mode and as a scheduled mode. The autonomous mode does not necessarily require a resource request-grant relationship between the transmitters and the receiver prior to a communication, while the scheduled mode requires the presence of an arbiter of some type (e.g., at the receiver) to authorize and/or schedule transmissions for the 20 multiple transmitters.

Each mode of operation has its advantages and its disadvantages. For example, the autonomous mode is well suited for small packet or circuit-like transmissions, while the scheduled mode is well suited for latency-insensitive transmissions.

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For the cdma2000 1xEV-DV (or cdma2000, Revision D) reverse link framework, it is desirable to support both the autonomous mode and the scheduled mode of operation for the Reverse Supplemental Channel (R-SCH). However, many technical issues need to be resolved to make the autonomous and scheduled modes mutually compatible. For 30 example, in order to operate these two modes alternatively, one important issue concerns how to best transition between the two modes.

Efforts have begun to standardize a complementary uplink structure, Enhanced Uplink Packet Access (EUPA) in 3GPP, to 1xEV-DV Revision D in 3GPP2. However, at present there is no provision for transitioning a mobile station between the autonomous and the scheduled transmission modes.

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As a result, as presently specified the base station may not know, at any given time, when the mobile station needs to transmit data in the packet data system.

SUMMARY OF THE PREFERRED EMBODIMENTS

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The foregoing and other problems are overcome, and other advantages are realized, in accordance with the presently preferred embodiments of these teachings.

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It is an aspect of this invention to define a procedure to accomplish a scheduled switching mode for transitioning a mobile station between the autonomous transmission mode and the scheduled transmission mode.

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Disclosed is a method for operating a mobile station with a base station, as well as apparatus for performing the method. The method includes, when the mobile station is in an Autonomous mode of operation, autonomously transmitting data from the mobile station to the base station on a reverse supplemental channel or a reverse access channel (e.g. R-EACH) from the mobile station to the base station; in response to receiving an acknowledgment indication from the base station, that comprises a reverse channel assignment message for the mobile station, switching the mobile station to a Scheduled mode of operation and transmitting the data from the mobile station on an assigned reverse channel.

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In the preferred embodiment, when initiating the data transmission of scheduled mode, the mobile station transmits a Supplemental Channel Request Message and the reverse access channel is a Reverse Enhanced Access Channel. The acknowledgment indication is sent as part of a Supplemental Channel Assignment Message and further includes power control bits and data rate grant bits, where the power control bits and data rate

grant bits are received by the mobile station on a Common Power Control Channel. Transmitting the data from the mobile station on the assigned reverse channel includes also transmitting mobile station buffer activity bits and a data rate request bit, and the method further includes receiving, from the base station, a power control bit, a data rate 5 grant bit and an ACK/NACK indication. The data rate request bit is preferably transmitted as part of a dynamic buffer status report, and requests one of an increase in data rate, a decrease in data rate, or no change in the data rate, and the data rate grant bit is time multiplexed by the base station with the power control bit, and indicates one of a grant of the requested data rate or a denial of the requested data rate.

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Also disclosed is a mobile station that includes an RF transceiver for conducting bidirectional wireless communications with a base station and a data processor that operates under the control of a stored program for, when the mobile station is in an Autonomous mode of operation, autonomously transmitting data from the mobile station 15 to the base station on a reverse supplemental channel or a reverse access channel from the mobile station to the base station. The data processor is responsive to a reception of an acknowledgment indication from the base station that comprises a reverse channel assignment message for the mobile station, for switching the mobile station to a Scheduled mode of operation and for transmitting the data from the mobile station on an 20 assigned reverse channel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of these teachings are made more evident in the 25 following Detailed Description of the Preferred Embodiments, when read in conjunction with the attached Drawing Figures, wherein:

Fig. 1 is a simplified block diagram of a mobile communications system that is suitable for practicing the teachings of this invention;

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Fig. 2 is a diagram for illustrating a state transition from an autonomous transmission mode to a scheduled transmission mode;

Fig. 3 is a state diagram that illustrates 1xEV-DV R-SCH states and transitions; and

5 Fig. 4 is a timing diagram that illustrates timing relationships between data rate request and grant, where the delays D1 and D2 are configurable by the base station.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

By way of introduction, and referring to Fig. 1, there is shown as a simplified block diagram an embodiment of a wireless communications system 10 that is suitable for practicing this invention. The wireless communications system 10 includes at least one mobile station (MS) 100. Fig. 1 also shows an exemplary network operator 20 having, for example, a node 30 for connecting to a telecommunications network, such as a Public Packet Data Network or PDN, at least one base station controller (BSC) 40 or equivalent apparatus, and a plurality of base transceiver stations (BTS) 50, also referred to as base stations (BSs), that transmit in a forward or downlink direction both physical and logical channels to the mobile station 100 in accordance with a predetermined air interface standard. A reverse or uplink communication path also exists from the mobile station 100 to the network operator, which conveys mobile originated access requests and traffic. A cell 3 is associated with each BTS 50, where one cell will at any given time be considered to be a serving cell, while an adjacent cell(s) will be considered to be a neighbor cell. Smaller cells (e.g., picocells) may also be available.

25 The air interface standard can conform to any suitable standard or protocol, and may enable both voice and data traffic, such as data traffic enabling Internet 70 access and web page downloads. In the presently preferred embodiment of this invention the air interface standard is compatible with a code division multiple access (CDMA) air interface standard, such as one known as cdma2000, although this is not a limitation upon the practice of this invention.

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The mobile station 100 typically includes a control unit or control logic, such as a microcontrol unit (MCU) 120 having an output coupled to an input of a display 140 and

an input coupled to an output of a keyboard or keypad 160. The mobile station 100 may be a handheld radiotelephone, such as a cellular telephone or a personal communicator. The mobile station 100 could also be contained within a card or module that is connected during use to another device. For example, the mobile station 10 could be contained 5 within a PCMCIA or similar type of card or module that is installed during use within a portable data processor, such as a laptop or notebook computer, or even a computer that is wearable by the user.

The MCU 120 is assumed to include or be coupled to some type of a memory 130, 10 including a non-volatile memory for storing an operating program and other information, as well as a volatile memory for temporarily storing required data, scratchpad memory, received packet data, packet data to be transmitted, and the like. At least some of this temporary data can be stored in a data buffer 130A. The operating program is assumed, for the purposes of this invention, to enable the MCU 120 to execute the software 15 routines, layers and protocols required to implement the methods in accordance with this invention, as described in detail below, as well as to provide a suitable user interface (UI), via display 140 and keypad 160, with a user. Although not shown, a microphone and speaker are typically provided for enabling the user to conduct voice calls in a conventional manner.

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The mobile station 100 also contains a wireless section that includes a digital signal processor (DSP) 180, or equivalent high speed processor or logic, as well as a wireless transceiver that includes a transmitter 200 and a receiver 220, both of which are coupled to an antenna 240 for communication with the network operator. At least one local 25 oscillator, such as a frequency synthesizer (SYNTH) 260, is provided for tuning the transceiver. Data, such as digitized voice and packet data, is transmitted and received through the antenna 240.

The following discussion first describes a plurality of reverse supplemental channel 30 (R-SCH) states and then describes state transitions. However, the teachings of this invention encompass all possible options for state design and state transitions. This invention also accommodates quality of service (QoS) needs for describing mode

transitions.

As was stated earlier, an aspect of this invention is to enhance the reverse link (uplink) for IS2000 by the addition of a mode for the MS 100 to transition to scheduling 5 transmissions when operating using autonomous transmissions. Fig. 2 depicts the scenario while the MS 100 is in the active state. The transition proceeds by the following Steps.

1. The MS 100 initiates data transfer on the R-EACH (Reverse Enhanced Access 10 Channel) or Reverse Supplemental Channel. A SCRM (supplemental channel request message) can be transmitted over a reverse fundamental or reverse dedicated channel to request a scheduled mode operation, if the mobile station so desires.
2. If the BS 50 acknowledges the MS 100 transmission it sends an acknowledgment 15 indicator (AI), if the reverse data is sent over the R-EACH in previous step. The base station also can send a SCAM (Supplemental Channel Assignment Message) for informing the MS 100 of its channel assignment over a forward fundamental or dedicated channel. In addition, the BS 50 sends, via the CPCCH (Common Power Control Channel), the PCB (power control bits), RGB (Rate Grant Bits), and the ACK/NAK bits.
- 20 In response, the MS 100 transmits its data along with BAB (Buffer Activity bits), reflecting utilization of the data buffer 130A in Fig. 1, and RRB (Rate Request bits).

If the BS 50 does not acknowledge the MS 100 transmission, i.e., the MS 100 is denied permission to transmit, the MS 100 repeats Step 1.

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3. Assuming that the MS 100 has permission to transmit, the MS 100 and BS 50 jointly "close the reverse data transmission loop" by the MS 100 sending its data, plus the BAB and RRB. The BS 50 responds with the PCB, the RGB and the appropriate one of ACK/NAK.

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When the MS 100 is in a Control Hold state the MS 100 first transitions out of the Control Hold state prior to initiating the data transfer.

It can be appreciated that the use of this invention solves the previously described problem of the BS 50 not having knowledge of when the MS 100 needs to transmit data. By the use of this invention the MS 100 is permitted to autonomously initiate the data transmission process, followed by BS 50 control of whether the data transmission may continue (entering into scheduled mode). The use of this invention can thus be seen to reduce the delay associated with reverse link transmission (startup). Furthermore, since the BS 50 has control of whether to permit the MS 100 to continue data transmission, the BS 50 can control the ROT (Rise Over Thermal).

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A more detailed description of this invention is now provided.

As is shown in Fig. 3, there are four R-SCH states/modes and eight transitions among these states/modes in cdma2000 1xEV-DV. Note that the terminologies of "state" and "mode" are interchangeable in the ensuing discussion. The four states are the R-SCH initialization state, the R-SCH autonomous state, the R-SCH scheduled state, and R-SCH release state. These are now described in further detail.

A. R-SCH Initialization State

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There are various possible (optional) ways to initialize the R-SCH in cdma2000 1xEV-DV.

Option 1:

25 The MS 100 sends a Supplemental Channel Request Message (SCRM) over the R-DCCH/R-FCH to the BS. The BS 50 acknowledges with Extended Supplemental Channel Assignment Message (ESCAM) over F-FCH/F-DCCH/F-PDCH. This is same as a conventional cdma2000 1xRTT approach.

30 Option 2:

The MS 100 sends a Supplemental Channel Request Mini Message (SCRMM) over the R-DCCH/R-FCH to the BS 50. The BS 50 acknowledges with a Supplemental Channel

Assignment Mini Message (SCAMM) over the F-FCH/F-DCCH/F-PDCH/F-CACH. This is also the same as the conventional 1xRTT approach.

Option 3:

5 The MS 100 sends a modified Supplemental Channel Request Message (SCRM) over the R-DCCH/R-FCH to the BS 50. The BS 50 acknowledges with a modified Extended Supplemental Channel Assignment Message (ESCAM) over the F-FCH/F-DCCH/F-PDCH/. The modified SCRM includes additional parameters such as the MS 100 buffer status, transmit power, QoS level and the MS 100 preferred mode of
10 R-SCH operation (either Autonomous or Scheduled mode). The modified ESCAM transmitted by the BS 50 includes additional parameters such as the MAC_ID (medium access control ID) to identify the MS 100 for R-SCH access, and the bit positions of control information (e.g. PC, RG, and A/N) in a power control subchannel (i.e., the F-FCH, F-DCCH, or F-CPCCH).

15 It should be noted that the MAC_ID can be the same as the MAC_ID for the F-PDCH, if the F-PDCH exists for the MS 100. Also, the MAC_ID in SCAM can be replaced with a mapping identifier serving as a reverse link R-SCH access ID.

20 Option 4:

The MS 100 sends the Supplemental Channel Request Message (SCRM) over the R-DCCH/R-FCH to the BS 50 (as in Option 1 above). The BS 50 acknowledges with a modified Extended Supplemental Channel Assignment Mini Message (ESCAMM) over the F-FCH/F-DCCH/F-PDCH/F-CACH. The ESCAMM includes parameters as in the
25 modified ESCAM of Option 3.

Option 5:

The MS 100 sends a request over the R-EACH with additional parameters. The additional parameters specify the R-SCH characteristic and its preferred mode of operation.

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R-SCH Autonomous Mode

In this mode of operation, the MS 100 can access the R-SCH without prior authorization. The operation in this mode has two options.

Option 1:

- 5 For fixed/constant data rate applications, all active MSs 100 can send data over the R-SCH autonomously using a data rate established by any of the following rules:
 - (1) at a lowest data rate, i.e. 9.6kbps,
 - (2) at a low fixed data rate that is configurable by the BS 50, or
- 10 (3) at a minimum rate that is dynamically agreed upon by the MS 100 and the BS 50. For example, the data rate may be negotiated between the MS 100 and BS 50 by exchanging QoS BLOB according to IS-2000.5 procedures.

It is noted that all active MSs 100 should have been assigned with a MAC_ID in the R-SCH initialization state or in the F-PDCH assignment phase. The MAC_ID is used by the BS 50 to distinguish between multiple autonomous mode MSs 100. However, the BS 50 also can distinguish multiple autonomous mode MSs 100 by decoding the MS 100 long code, without having knowledge of the MAC_ID.

- 20 This option can be used to advantage for short frame transmission or low data rate applications.

Option 2:

Similar to the cdma20001xEV-DO (also referred to as HDR), the MS 100, along with the R-SCH user traffic transmission, can explicitly send Rate Indication information over a reverse channel to indicate the data rate that is being used in the present R-SCH frame. The reverse Rate Indication channel may be a separate dedicated Walsh-coded channel, a common channel, or a channel that is time-multiplexed with other channels.

- 30 R-SCH Scheduled Mode

There are two options available for the R-SCH scheduled mode.

Option 1:

Similar to cdma2000 1xRTT, the R-SCH procedures and relevant messages are used. The MS 100 requests R-SCH channel assignment, and the BS 50 schedules and assigns a

5 R-SCH channel with a specific data rate and time duration.

Option 2:

For variable data rate applications, the following mode of operation can also be considered as a "semi-scheduled" mode.

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MS 100 Procedures:

The MS 100 begins with the autonomous mode at a low data rate, as defined above.

While sending data over the R-SCH, the MS 100 also sends a "Data Rate Request" to the BS 50. The Data Rate Request has the following characteristics. The Data Rate Request

15 is 1-bit of information with three-state modulation (i.e., -1, 0, and 1), and it may be carried over an uplink overhead dedicated or common channel, or it may be carried over the R-SCH with a special Multiplexing option, where the MS 100 traffic and control information are multiplexed. The Data Rate Request may also be reflected in the MS 100 dynamic buffer status, QoS level and transmit power report to the BS 50. In other words,

20 the Data Rate Request bit can be referred to as the BAB (buffer activity bit). The definition of the Data Rate Request is as follows:

If **BAB = INCREASE = 1**, the MS 100 is requesting to transmit on the R-SCH at the data rate of (current data rate + incremental rate), where the incremental rate = increased step rate,

25 If **BAB = DECREASE = -1**, the MS 100 is requesting to transmits on the R-SCH at the data rate of (current data rate - decremented rate),

If **BAB = CONSTANT = 0**, the MS 100 is requesting to transmit on the R-SCH at the same data rate as the current data rate.

30 **BS 50 Procedures:**

Upon receiving the Data Rate Request of one of INCREASE/DECREASE/CONSTANT from the MS 100, the BS 50 acknowledges (i.e., it either grants or denies) the MS 100

with a 1-bit information (feedback) of GRANT/DENY. This 1-bit information has the following characteristics. It is carried over the power control sub-channels within the F-FCH, F-DCCH, or F-CPCCH, and is time-multiplexed with the power control bit (in F-FCH, F-DCCH, or F-CPCCH) and other control information. For higher transmission

5 reliability of this bit, bit repetition may be used by the BS 50. A definition of the GRANT/DENY bit is as follows.

If the 1-bit feedback = GRANT = 1, the BS 50 allows the MS 100 BAB request.

If the 1-bit feedback = DENY = -1, the BS 50 denies the MS 100 BAB request.

10 The autonomous data rate request (by the MS 100) and the grant (by the BS 50) have a certain timing relationship. Fig. 4 illustrates one non-limiting example of the timing relationship. Special notes for the timing relationship shown in Fig. 4 are as follows.

For Step 1-a (top trace) and 1-b (second to top trace), at any Power Control Group (PCG),

15 where there are 16 PCGs in one 20 ms frame) any MS 100 (e.g. MS 100 #1 or MS 100 #2) can request to increase, decrease, or maintain the data rate. After Delay time D1, the BS 50 receives and processes the request. The BS 50 sends the acknowledgment to MS 100 at the designated PCG. After Delay time D2, the MS 100 starts transmitting on the R-SCH at the data rate that is agreed upon with the BS 50. The rate control can be "per 20 PCG" or "per frame", and the value of D1 and D2 is controlled or configured by the BS 50.

R-SCH Release State

This state can be similar to that of cdma2000 1xRTT.

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R-SCH State/Mode Transitions

The events (or methods) for the eight transitions shown in the state diagram of Fig. 2 are described as follows.

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Transition 1: The preferred mode of operation is embedded in the (modified) R-SCH assignment (mini) message.

Transition 2: The preferred mode of operation is embedded in the (modified) R-SCH assignment (mini) message.

Transition 3: For Option 1, the MS 100 remains in the Autonomous mode when it is continuing transmission at the low (or lowest) data rate. For Option 2, the MS 100

5 remains in the Autonomous mode when the reverse rate indication indicates a legitimate data rate (instead of a mode switch indication).

Transition 4: The MS 100 remains in the Scheduled Mode so long as there is no new mode switch request in the SCRM, or the MS 100/BS 50 still operate based on the data rate request-grant "scheduled" procedures defined herein.

10 Transition 5: For Option 1, the preferred mode of operation is embedded in the (modified) R-SCH assignment (mini) message. For Option 2, the transition trigger may be implemented with the QoS level, with higher QoS needs corresponding to the Scheduled Mode and its transition.

Transition 6: For Option 1, the R-SCH-assigned duration timer is used as the trigger, i.e.,

15 after the duration of the scheduled transmission, the MS 100 reverts back to the Autonomous Mode. For Option 2, the preferred mode of operation is embedded in the (modified) R-SCH assignment (mini) message. For Option 3, the transition trigger may be implemented with the QoS level model, with lower QoS needs corresponding to the Autonomous Mode and its transition.

20 Transition 7: This can be similar to 1xRTT, using R-SCH release messages and procedures.

Transition 8: This can also be similar to 1xRTT, using R-SCH release messages and procedures.

25 As has been described, for the cdma2000 1xEV-DV reverse link framework it is desirable to support both the Autonomous and the Scheduled Modes of operation for the R-SCH. The foregoing discussion of the invention has described each R-SCH state and state transition in detail, and furthermore applies equally to other possible state designs and state transitions. The QoS parameters can be used to support the presently preferred state
30 transitions.

The foregoing description has provided by way of exemplary and non-limiting examples

a full and informative description of the best method and apparatus presently contemplated by the inventors for carrying out the invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such modifications of the teachings of this invention will still fall within the scope of this invention. Further, while the method and apparatus described herein are provided with a certain degree of specificity, the present invention could be implemented with either greater or lesser specificity, depending on the needs of the user. Further, some of the features of the present invention could be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles of the present invention, and not in limitation thereof, as this invention is defined by the claims which follow.